

WHAT IS CLAIMED IS:

- 1 1. A method of manufacturing an inter-level dielectric (ILD) layer of a semiconductor device, the method comprising:
  - 3 forming a first low-dielectric constant material sub-layer over the substrate, the first low-dielectric constant material having at least one first material property;
  - 5 forming a second low-dielectric constant material sub-layer over the first low-dielectric constant material sub-layer, the second low-dielectric constant material sub-layer having at least one second material property, wherein the at least one second material property is different from the at least one first material property; and
  - 9 forming a third low-dielectric constant material sub-layer over the second low-dielectric constant material sub-layer, the third low-dielectric constant material sub-layer having at least one third material property, the at least one third material property being different from the at least one second material property.
- 1 2. The method according to Claim 1, wherein forming the ILD layer comprises forming the first low-dielectric constant material sub-layer, second low-dielectric constant material sub-layer, and third low-dielectric constant material sub-layer from methylsilsesquioxane (MSQ), a MSQ derivative, hydridosilsesquioxane (HSQ), a HSQ derivative, an oxide and MSQ hybrid, a porogen/MSQ hybrid, an oxide and HSQ hybrid, a porogen/HSQ hybrid, or combinations thereof.

1    3.    The method according to Claim 1, wherein forming the ILD layer comprises forming the  
2    first low-dielectric constant material sub-layer, second low-dielectric constant material sub-layer,  
3    and third low-dielectric constant material sub-layer continuously from the same material in one  
4    or more deposition chambers.

1    4.    The method according to Claim 1, wherein forming the ILD layer comprises forming the  
2    first low-dielectric constant material sub-layer, second low-dielectric constant material sub-layer,  
3    and third low-dielectric constant material sub-layer while adjusting the deposition conditions.

1    5.    The method according to Claim 4, wherein adjusting the deposition conditions comprises  
2    adjusting the gas flow rate, power, or gas species.

1    6.    The method according to Claim 1, wherein the first material property, second material  
2    property, and third material property comprise density, dielectric constant, adhesion, or Young's  
3    modulus.

1    7.    The method according to Claim 1, further comprising forming at least one fourth low-  
2    dielectric constant material sub-layer over the third low-dielectric constant material sub-layer,  
3    the fourth low-dielectric constant material sub-layer having at least one fourth material property,  
4    wherein the at least one fourth material property is different from the at least one third material  
5    property.

1 8. A method of manufacturing a semiconductor device, the method comprising:

2 providing a substrate, the substrate having component regions formed thereon;

3 forming a first etch stop layer over the substrate;

4 forming a first ILD layer over the first etch stop layer; and

5 forming at least one first conductive region in the first ILD layer and first etch stop layer,

6 wherein at least one first conductive region makes electrical contact with at least one component

7 region of the substrate, and wherein forming the first ILD layer comprises:

8 forming a first low-dielectric constant material sub-layer over the first etch stop

9 layer;

10 forming a second low-dielectric constant material sub-layer over the first low-

11 dielectric constant material sub-layer, the second low-dielectric constant material sub-layer

12 having at least one different material property than the first low-dielectric constant material sub-

13 layer; and

14 forming a third low-dielectric constant material sub-layer over the second low-

15 dielectric constant material sub-layer, the third low-dielectric constant material sub-layer having

16 at least one different material property than the second low-dielectric constant material sub-layer.

1 9. The method according to Claim 8, wherein forming the first ILD layer comprises forming

2 the first low-dielectric constant material sub-layer, second low-dielectric constant material sub-

3 layer, and third low-dielectric constant material sub-layer from methylsilsesquioxane (MSQ), a

4 MSQ derivative, hydridosilsesquioxane (HSQ), a HSQ derivative, an oxide and MSQ hybrid, a

5 porogen/MSQ hybrid, an oxide and HSQ hybrid, a porogen/HSQ hybrid, or combinations

6 thereof.

1 10. The method according to Claim 8, wherein forming the first ILD layer comprises forming  
2 the first low-dielectric constant material sub-layer, second low-dielectric constant material sub-  
3 layer, and third low-dielectric constant material sub-layer continuously from the same material in  
4 one or more deposition chambers.

1 11. The method according to Claim 8, wherein forming the first ILD layer comprises forming  
2 the first low-dielectric constant material sub-layer, second low-dielectric constant material sub-  
3 layer, and third low-dielectric constant material sub-layer while adjusting the deposition  
4 conditions.

1 12. The method according to Claim 8, wherein adjusting the deposition conditions comprises  
2 adjusting the gas flow rate, power, or gas species.

1 13. The method according to Claim 8, wherein the material property of the second low-  
2 dielectric constant material sub-layer and the material property of the third low-dielectric  
3 constant material sub-layer comprise density, dielectric constant, adhesion, or Young's modulus.

1 14. The method according to Claim 8, further comprising forming at least one fourth low-  
2 dielectric constant material sub-layer over the third low-dielectric constant material sub-layer,  
3 the fourth low-dielectric constant material sub-layer having at least one different material  
4 property than the third low-dielectric constant material sub-layer.

1 15. The method according to Claim 8, further comprising;

2 forming a second etch stop layer over the first ILD layer;

3 forming a second ILD layer over the second etch stop layer; and

4 forming at least one second conductive region in the second ILD layer and second etch

5 stop layer, wherein the at least one second conductive region makes electrical contact with at

6 least one first conductive region, and wherein forming the second ILD layer comprises:

7 forming a fourth low-dielectric constant material sub-layer over the second etch

8 stop layer;

9 forming a fifth low-dielectric constant material sub-layer over the fourth low-

10 dielectric constant material sub-layer, the fifth low-dielectric constant material sub-layer having

11 at least one different material property than the fourth low-dielectric constant material sub-layer;

12 and

13 forming a sixth low-dielectric constant material sub-layer over the fifth low-

14 dielectric constant material sub-layer, the sixth low-dielectric constant material sub-layer having

15 at least one different material property than the fifth low-dielectric constant material sub-layer.

1 16. An inter-level dielectric (ILD) layer of a semiconductor device, comprising:

2       a first low-dielectric constant material sub-layer, the first low-dielectric constant material

3       having at least one first material property;

4       a second low-dielectric constant material sub-layer disposed over the first low-dielectric

5       constant material sub-layer, the second low-dielectric constant material sub-layer having at least

6       one second material property, wherein the at least one second material property is different from

7       the at least one first material property; and

8       a third low-dielectric constant material sub-layer disposed over the second low-dielectric

9       constant material sub-layer, the third low-dielectric constant material sub-layer having at least

10      one third material property, the at least one third material property being different from the at

11      least one second material property.

1 17. The ILD layer according to Claim 16, wherein the first low-dielectric constant material

2       sub-layer, second low-dielectric constant material sub-layer, and third low-dielectric constant

3       material sub-layer comprise methylsilsesquioxane (MSQ), a MSQ derivative,

4       hydridosilsesquioxane (HSQ), a HSQ derivative, an oxide and MSQ hybrid, a porogen/MSQ

5       hybrid, an oxide and HSQ hybrid, a porogen/HSQ hybrid, or combinations thereof.

1 18. The ILD layer according to Claim 16, wherein the first low-dielectric constant material

2       sub-layer, second low-dielectric constant material sub-layer, and third low-dielectric constant

3       material sub-layer are formed continuously from the same material in one or more deposition

4       chambers.

1 19. The ILD layer according to Claim 16, wherein the first material property, second material  
2 property, and third material property comprise density, dielectric constant, adhesion, or Young's  
3 modulus.

1 20. The ILD layer according to Claim 16, further comprising at least one fourth low-  
2 dielectric constant material sub-layer disposed over the third low-dielectric constant material  
3 sub-layer, the fourth low-dielectric constant material sub-layer having at least one fourth material  
4 property, wherein the at least one fourth material property is different from the at least one third  
5 material property.

1 21. A semiconductor device, comprising:

2 a substrate, the substrate having component regions formed thereon;

3 a first etch stop layer disposed over the substrate;

4 a first ILD layer disposed over the first etch stop layer; and

5 at least one first conductive region formed in the first ILD layer and first etch stop layer,

6 wherein at least one first conductive region makes electrical contact with at least one component

7 region of the substrate, and wherein the first ILD layer comprises:

8 a first low-dielectric constant material sub-layer disposed over the first etch stop

9 layer;

10 a second low-dielectric constant material sub-layer disposed over the first low-

11 dielectric constant material sub-layer, the second low-dielectric constant material sub-layer

12 having at least one different material property than the first low-dielectric constant material sub-

13 layer; and

14 a third low-dielectric constant material sub-layer disposed over the second low-

15 dielectric constant material sub-layer, the third low-dielectric constant material sub-layer having

16 at least one different material property than the second low-dielectric constant material sub-layer.

1 22. The semiconductor device according to Claim 21, wherein the first low-dielectric

2 constant material sub-layer, second low-dielectric constant material sub-layer, and third low-

3 dielectric constant material sub-layer comprise methylsilsesquioxane (MSQ), a MSQ derivative,

4 hydridosilsesquioxane (HSQ), a HSQ derivative, an oxide and MSQ hybrid, a porogen/MSQ

5 hybrid, an oxide and HSQ hybrid, a porogen/HSQ hybrid, or combinations thereof.

1 23. The semiconductor device according to Claim 21, wherein the first low-dielectric  
2 constant material sub-layer, second low-dielectric constant material sub-layer, and third low-  
3 dielectric constant material sub-layer are formed continuously from the same material in one or  
4 more deposition chambers.

1 24. The semiconductor device according to Claim 21, wherein the different material property  
2 of the second low-dielectric constant material sub-layer and third low-dielectric constant material  
3 sub-layer comprises density, dielectric constant, adhesion, or Young's modulus.

1 25. The semiconductor device according to Claim 21, further comprising at least one fourth  
2 low-dielectric constant material sub-layer disposed over the third low-dielectric constant material  
3 sub-layer, the fourth low-dielectric constant material sub-layer having at least one different  
4 material property than the third low-dielectric constant material sub-layer.

1 26. The semiconductor device according to Claim 21, further comprising;

2       a second etch stop layer disposed over the first ILD layer;

3       a second ILD layer disposed over the second etch stop layer; and

4       at least one second conductive region disposed in the second ILD layer and second etch

5 stop layer, wherein the at least one second conductive region makes electrical contact with at

6 least one first conductive region, and wherein the first ILD layer comprises:

7           a fourth low-dielectric constant material sub-layer disposed over the second etch

8 stop layer;

9           a fifth low-dielectric constant material sub-layer disposed over the fourth low-

10 dielectric constant material sub-layer, the fifth low-dielectric constant material sub-layer having

11 at least one different material property than the fourth low-dielectric constant material sub-layer;

12 and

13           forming a sixth low-dielectric constant material sub-layer over the fifth low-

14 dielectric constant material sub-layer, the sixth low-dielectric constant material sub-layer having

15 at least one different material property than the fifth low-dielectric constant material sub-layer.

1 27. The semiconductor device according to Claim 21, wherein the first low-dielectric

2 constant material sub-layer comprises a first Young's modulus, wherein the first Young's

3 modulus is greater than a second Young's modulus of the second low-dielectric constant material

4 sub-layer and a third Young's modulus of the third low-dielectric constant material sub-layer.

1 28. The semiconductor device according to Claim 21, wherein the first low-dielectric  
2 constant material sub-layer comprises a first dielectric constant, wherein the first dielectric  
3 constant is greater than a second dielectric constant of the second low-dielectric constant  
4 material sub-layer and a third dielectric constant of the third low-dielectric constant material sub-  
5 layer.

1 29. The semiconductor device according to Claim 21, wherein the first low-dielectric  
2 constant material sub-layer is more adhesive than the second low-dielectric constant material  
3 sub-layer and the third low-dielectric constant material sub-layer.